SELF-CALIBRATING METHOD FOR MEASURING THE DENSITY AND VELOCITY OF SOUND FROM TWO REFLECTIONS OF ULTRASOUND AT A SOLID-LIQUID INTERFACE

BACKGROUND

1. Field of the Invention

The present invention relates to fluid analysis and more particularly, but not exclusively, to the determination of fluid properties at a solid-liquid interface without the necessity of timing the passage of ultrasound through the liquid.

2. Background of the Invention

Fluids are encountered in a wide variety of industrial applications and there is a continual need to determine properties of those fluids. A variety of methods exist, including those set forth by the present inventor in U.S. Pat. No. 6,763,698 and U.S. Pat. No. 6,877,375, the contents of which are herein incorporated by reference. The present invention provides an improved method for determining characteristics of a liquid or slurry without requiring the passage of ultrasound through this media. The present invention also allows for increased accuracy in making determinations related to the materials being tested, as well as avoids problems associated with other methods such as the impact of bubbles, attenuative fluids, or large sample volumes upon proper determinations.

Additional advantages and novel features of the present invention will be set forth as follows and will be readily apparent from the descriptions and demonstrations set forth herein. Accordingly, the following descriptions of the present invention should be seen as illustrative of the invention and not as limiting in any way.

BRIEF DESCRIPTION OF THE VIEWS OF THE DRAWING

FIG. **1** is a diagrammatic view of system for determining fluid properties.

FIG. **2***a* is a detailed view of the portion of the system shown in FIG. **1**.

FIG. **2***b* is a detailed view of an alternate embodiment of the system shown in FIG. **2***a*.

FIG. **3** is a view of an incident wave against a surface.

FIG. **4** is a view of a portion of the block of the present invention.

FIG. **5** is a view of multiple echoes.

FIG. **6** is a graph of a single echo.

FIG. **7** is a graph of the FFT values for the signal in FIG. **6**.

FIG. **8** is a graph relating the natural logarithm of FFT amplitude of each echo divided by that for water to the echo number.

FIG. **9** is a chart showing the correlative results of the measured values for the reflection coefficient compared to the theoretical values.

DETAILED DESCRIPTION

For the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications in the described embodiments, and any further applications of the principles of the invention as described herein, are contemplated as would normally occur to one skilled in the art to which the invention relates.

Turning now to FIG. **1**, a system **20** for analyzing a property of fluid **25** is depicted. Fluid **25** can be a gas, liquid, slurry, suspension, paste, emulsion and the like. In preferred forms, fluid **25** is substantially non gaseous and/or includes at least one liquid. In this form, fluid **25** might be, for example, a liquid, slurry, or suspension. Ultrasonic transducer **30** is acoustically coupled to a first surface **42** of a member **40** comprised of a solid material. In one example, transducer **30** is in direct contact with member **40**. In other examples, one or more couplants might be used between transducer **30** and member **40**, or they may be coupled as would otherwise occur to those skilled in the art. An opposed second surface **44** of member **40** is in contact with the fluid **25**. A pulser **50** is electrically coupled to transducer **30** and is operable to deliver input stimulus signal to transducer **30** to cause transducer **30** to emit acoustic energy through solid member **40** and towards fluid **25**. Transducer **30** is also operable to produce output signals in response to acoustic energy transmitted from member **40**.

A shear wave inducing transducer **31** is also mounted to the member **40** in a manner so that transmissions propogated by the shear wave inducing transducer **31** are reflected off of the interface **23** of the member **40** and the surface of the fluid **25** being analyzed. In the preferred embodiment this shear wave inducing transducer emits ultrasound at a generally 45 degree angle to the surface/fluid interface **23** through an angle block **33** which may be attached as a portion of the member **40** itself. The shear wave transducer **31** produces transverse waves that are perpendicular to the direction of motion of the wave. In addition, shear wave transducer **31** is oriented on member **40** so that shear-vertical waves SV are produced. For purposes of understanding the directions of these waves in relation to the other portions of the device, in a shear wave transducer, the vibrations are in the plane of the paper and shear horizontal waves SH producing vibrations that are perpendicular to the plane of the paper. The reflection of SV and SH waves at a solid-liquid interface **23** are extremely different.

In the embodiment shown in FIG. **2***a*, this angle block **33** which is made of a material such as quartz and is positioned within a window whereby the angled transmission from the angled transducer **31** to the interface **23** does not pass through any other materials that are not a part of the angle block **33**. In an alternative embodiment shown in FIG. **2**(*b*) the shear wave transducer **31** and the angle block **33** are connected to the outer portion of the conduit member **40**. In such an embodiment the angle block **33** is made from a material such as stainless steel or other similar types of material. This angle block is generally configured so that the shear wave transducer **31** is positioned at a general angle of 45°. This angle is generally preferred because a reflected longitudinal wave cannot generally occur at this angle. In addition to transmitting at a 45° angle this angle block **33** also serves to reflect transmitted shear waves back towards the interface **23**, and in turn back towards the shear wave emitting transducer **31**. These reflected waves are also received by the shear wave inducing transducer **31** which then transmits a quantity of information related to this wave back to the processing apparatus **22**.

In one embodiment, the processing apparatus **22** including receiver **60**, digitizer **70**, and computer **80**, is coupled to pulser **50** and to transducers **30**, **31**. Processing apparatus **22** controls delivery of output signals to each of the two transducers **30**, **31** and receives the input signals from the transducers **30**, **31** and, as described more fully below, performs